Cone Beam Computed Tomography : An essential ally to Undergraduates in their Dental Practice

Abstract:
Cone beam computed tomography (CBCT) has developed into a crucial technique in contemporary dentistry, enabling dentists to examine the interaction between teeth and the tissues around them. The use of CBCT, improves the precision of diagnoses, planning, and follow-up in difficult patients. In order to give clinically valuable information based on a set of volumetric data, image post-processing and subsequent visualization rely on software for 3D navigation and application of indexation techniques. Diagnostic quality relies heavily on image post-processing, and a variety of methods have been used, including multiplanar reformations, maximum intensity projection, and volume rendering. CBCT is expected to be used routinely in most offices during the next few decades and shall be considered the "gold standard" for imaging of the oral and maxillofacial region.

Key-words: Cone-Beam Computed Tomography, Clinical Competence, Dental Offices

Introduction:

A precise diagnosis is essential for creating a workable treatment plan, and it must be supported with measurements and photographs of the craniofacial region that are accurate.

In dentistry, technological advancements are happening at an exponential rate. In the past thirty years, there have been significant technological advancements in dental radiology. We have transitioned from two-dimensional to three-dimensional imaging and from conventional to digital radiography over that time. Dental professionals now use 3D craniofacial imaging technology for diagnosis and treatment planning.[1]

Cone beam computed tomography is a new technology that has recently drawn interest from the dental community (CBCT). As a result, the way that diagnosis is approached has changed, with conventional radiography losing importance.

In dentistry, CBCT has been utilized for diagnosis and treatment planning as well as for the evaluation of caries, periodontal issues, periapical illnesses, trauma, impacted third molars, and the temporomandibular joint.

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In the near future, all of these and many additional applications that profit from seeing narrow slices through the region of interest without superimposing local complex onto the image will become the norm for quality.[2]This article's main goal is to raise awareness among undergraduates of the emerging role of CBCT in dentistry.

History:

Three-dimensional radiographic imaging was first envisioned in the early 20th century and was proved by calculating an infinite number of projections of the image of a three-dimensional object. Computed Tomography (CT) scanners were first used to examine the human cranium. Initial devices

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provided cross-sectional images of 1 cm thickness. By 1980s it was reduced to 1.5 to 2 mm thick images. The manufacturers of subperiosteal implants introduced CT scans in dentistry and used axial images for treatment planning. In the last decade, CT scans have become one of the most frequently used imaging techniques for preoperative evaluation of the jaws before implant treatment. The first commercially developed program was DentaScan (General Electric, Milwaukee, Wis), which produced "dentist-friendly" images.[1,2]

In 1996, Quantitative Radiology (Verona, Italy), NewTom 9000, produced the first cone-beam computed tomography (CBCT) device. Although Mozzo et al. published their initial findings in 1998, the first CBCT equipment used in dentistry (Tacconi and Mozzo) debuted in 1995. In 2004, the first use of CBCT was made with a resolution of 0.15 mm, outperforming traditional CT. The use of CBCT for imaging the craniofacial complex have been increased in the last few years. CBCT has various advantages over 2 dimensional (2D) pictures, including delivering 1 : 1 orthogonal reconstruction of structures, and gives a relatively lower radiation dose than standard CT procedures. CBCT images can replace other 2D images like lateral cephalograms and panoramic radiography projections since the application can produce these images from the 3D data. According to studies, there is a wide range in the radiation exposure levels experienced by different CBCT machines. By controlling the field of view and intensity, these levels can be reduced. CBCT is less expensive and involves a smaller system, thus providing in-office imaging. It provides multi-planar image reconstruction and has higher spatial resolution, providing better visualization of mineralized structures. The display modes are exclusive for oral and maxillofacial imaging with fewer imaging artifacts. However, it has scattered radiation with limited contrast resolution and soft tissue contrast.[2]

Principle of CBCT:

Axial plane slices or a continuous spiral motion across the axial plane are captured by conventional CT equipment with a fan-shaped X-ray beam. Instead of the slice-by-slice imaging found in traditional CT, a CBCT machine uses a cone-shaped beam and a reciprocating solid-state flat panel detector that rotates once around the patient, 180–360 degrees, covering the defined anatomical volume (complete dental/ maxillofacial volume or limited regional area of interest). Unlike stacked axial slices found in CT, this single scan (rotation) takes planned data, significantly lowering the absorbed x-ray dose from 6 to 15 times that of CT. The scanning period of CBCT equipment ranges between 5 and 40 seconds depending on the manufacturer. With a typical working range of 1–15 mA at 90–120 kVp, CBCT has X-ray parameters similar to panoramic radiography. The computer instantly transmits the acquired 2D images, which then reconstructs into an anatomical volume for 1:1 ratio viewing in the axial, coronal, and sagittal planes (orthogonal planes). The information is in Digital Imaging and Communications in Medicine (DICOM) format, making it simple to communicate and use with other imaging programs from external sources. [2,3]

The majority of CBCT equipment includes convenient viewing software with fundamental 3D imaging tools. Along with these, third-party software is employed to create surgical guides, virtual study prototypes, and laser-generated resin models to facilitate diagnosis, treatment planning, and treatment delivery. The ability to interact with the data and produce images that resemble those typically used in clinical settings is the biggest feasible advantage of CBCT in dental imaging. These successfully interpreted, evaluated, and measured recreated images were used to establish diagnostic and therapeutic plans.[3]

In addition to basic orthogonal views, the CBCT offers the following display modes.

Oblique slicing: Because the data sets are isotropic, it is possible to slice the CBCT pictures non-axially and at any angle to produce multiplanar reformations (MPR). By cutting across a group of axial images, this function generates 2D images at any angle, aiding in the evaluation of certain structures (such as impacted teeth and the TMJ).

Curved slicing: This makes it possible to display a trace view by tracing the jaw arch, giving a familiar panorama-like picture.

Cross-sectional (oblique coronal) view: Using this function, the thickness is chosen and spacing of a series of cross-sectional images that are created successively and perpendicular to the curved slice is done. These images are helpful in assessing the morphological properties of alveolar bone for implant placement, the relationship between the third molar and the mandibular canal in the mandible, the condylar surface and shape in symptomatic TMJ problems, and pathological conditions affecting the jaws.

Ray Sum: By adding together adjacent voxels, the Ray Sum function allows the visualization of the thickened MPR slices. 'Ray sum' image designates the precise volume of the patient and can be used to create virtual projections, such as panoramic or cephalometric pictures that are equivalent to traditional radiographs without magnification and parallax distortion

Volume Rendering: With the help of this feature, you can visualize volume by choosing displaying certain voxels within a data set. The commonly used tool are direct volume rendering and indirect volume rendering. The process of direct volume rendering are Selecting an arbitrary threshold of voxel values below or over which all gray values are rejected. Although there are many different methods, maximum intensity projection (MIP) is the most used. The voxels that have the highest density values within a given thickness are shown in an image by MIP. Voxel values below a predetermined threshold are disregarded. MIP pictures are excellent for finding impacted teeth, evaluating the TMJ, determining the severity of fractures, analyzing the craniofacial region, monitoring the healing process after surgery, and spotting soft tissue calcifications. By choosing the density of the voxels to be displayed across the board (referred to as "segmentation"), indirect volume rendering (IVR) creates a volumetric surface reconstruction with depth. There are two different types of views that are possible: solid views (surface rendering) and translucent views (volumetric rendering). IVR is best for visualizing and analyzing craniofacial circumstances and figuring out how different anatomical elements, for example the link between the inferior alveolar canal and the mandibular third molar, relate to one another.[3]

Applications of Cbct in Different Specialites of Dentistry Orthodontics: [4]

With a practical 1:1 measuring ratio, CBCT provides superimposition-free, magnification-self-corrected pictures that are ideal for morphometric examination of structures and anatomic relationships, which is necessary for addressing different orthodontic needs. Assessment of palatal bone thickness, skeletal growth patterns, dental age estimation, visualization of impacted teeth, determination of available alveolar bone width for buccolingual movement of teeth, assessment of the upper airway, and planning of orthognathic and facial orthomorphic surgeries are some of the uses of orthodontics. The best method for determining facial growth, age, airway function, and abnormalities in tooth eruptive patterns has been found to be the availability of software such as Dolphin, In Vivo Dental and i-CAT™ in combination with CBCT pictures for cephalometric analysis. CBCT offers visual instructions for placing mini implants safely, preventing unintentional damage to critical structures that cannot be repaired.

Oral and Maxillofacial Surgery: [5]

Given the limitations of 2D images, such as structural superimpositions, CBCT permits precise measurement of surface distances, due to its precision and accurate image, it is preferred for evaluation. These benefits of CBCT have made it the preferred method for exploring and handling dentofacial discrepancies, cleft palate, midfacial and orbital fractures, including dentoalveolar fractures, post fracture evaluation, interoperative visualization of the maxillofacial bones, and more. The location of pathologic calcifications, such as tonsillitis, lymph nodes, and salivary gland stones, can also be used to separate them from other calcifications that may be of interest, like those in the carotid artery. The 3D views provided by CBCT have proved crucial for assessing unerupted, impacted, or extra teeth as well as their relationships to important structures. CBCT scans are also used for osteonecrotic alterations of the jaws, such as medication-related osteonecrosis of the jaw, and for pre- and post-surgical evaluation of bone graft receiver sites. Although CBCT imaging does not give adequate soft tissue contrast, the morphologic appearances and severity of lesions in the para nasal air sinuses are primarily well seen (e.g., retention pseudocyst). Patients with obstructive sleep apnea can benefit from pre-treatment evaluations using CBCT-derived pictures, which can also be used to choose the best surgical approach.

Implant Dentistry: [6,7]

To successfully replace missing teeth with dental implants and to prevent damage to nearby important tissues, the implant location must be accurately assessed. CBCT is the best option since it provides correct information about important structures, the height and width of the intended implant site, bone density, and the contour of the alveolus while exposing patients to minimal radiation. This has decreased implant failure rates. CBCT can be used to evaluate bone grafts and the placement of the implant in the alveolus after surgery. Additionally, a surgical guide is created that offers precise instructions for positioning the suggested implants. Given the image acquisition techniques used in CBCT machines, the bone density numbers derived from this technology cannot be established over a group of CBCT machines or individuals, unlike Hounsfield unit (HU) numbers derived from conventional CT, which are accurate and can be correlated with HU units.

Endodontics: [8]

According to published research, CBCT imaging is preferable to 2D imaging for the description of periapical lesions because it shows clear image of how the lesions are adjacent to the maxillary sinus, how the sinus membrane is affected, and where they are in relation to the mandibular canal. The quantity and morphology of roots and associated canals, working lengths, the type and degree of root angulation, as well as a true evaluation of current root canal obturations, can all be determined using CBCT. Additionally, it has been advised that CBCT be used to categorize the etiology of the lesion as endodontic or non-endodontic, which may have an impact on the treatment strategy. Due to the lack of superimpositions and projection difficulties in 2D imaging, it is possible to detect horizontal root fractures, vertical root fractures, and the depth of dentin fracture. Compared to 2D imaging, CBCT imaging can not only determine the amount of a lesion but also enable early detection of root resorption (internal or external). CBCT pictures make it easier to depict pulpal expansions in talon cusps and locate damaged instruments. Because of its dependability and accuracy, CBCT images can be used to assess the biomechanical preparation of root canals utilizing a variety of techniques.

Periodontics: [8]

2D imaging was foundation of periodontal diagnostics for years, however due to its limitations, the amount of bone loss could be underestimated or overestimated. According to the literature, morphometric analysis of periodontal disorders with CBCT is just as accurate as direct measurement with a periodontal probe. Due to the lack of superimposition of the structures, CBCT is also significantly superior to 2D radiography in terms of visualizing buccal and lingual abnormalities. With the help of CBCT, doctors can precisely measure intrabony defects, the postsurgical effects of regenerative periodontal therapy, and assess furcation involvement, dehiscence, fenestration defects, and periodontal cysts.

Application in Temporomandibular Disorders: [9]

To analyze TMJ and function, CBCT imaging provides multiplanar and possibly three-dimensional pictures of the condyle and surrounding tissues. The joint space and actual position of the condyle within the fossa can be examined using CBCT, which is useful in identifying the possibility of the joint disk dislocating. Additionally, CBCT helps locate the soft tissue around the TMJ and measures the roof of the glenoid fossa, enabling a realistic diagnosis and avoiding the need for magnetic resonance imaging. CBCT is the ideal imaging tool for example area including condylar developmental defects, trauma, fibro-osseous ankylosis, discomfort, dysfunction, condylar cortical erosion, rheumatoid arthritis, and cysts.

Forensic Odontology: [10]

Age estimation is an important aspect of forensic dentistry. Enamel is typically resistant to changes beyond regular wear and tear; nonetheless, with advancing age, the pulpodentinal complex exhibits physiologic and pathological changes. Typically, tooth extraction and sectioning are required to quantify these alterations, which is not always a practical option. However, CBCT provides a non-invasive alternative.

Virtual treatment planning and simulations: [11]

Virtual treatment planning, is possible using the software (main or third-party) provided with CBCT images. This planning can then be transported to the surgical site either directly by using image guided navigation or indirectly by building surgical guides. The surgical guides may be manufactured by rapid prototyping or may be modified laboratory imaging stents. Utilizing three-dimensional computer-aided design (CAD) data, a scale model of a physical item or assembly can be swiftly constructed utilizing a variety of processes known as rapid prototyping. The majority of the time, "additive layer manufacturing" or 3D printing is used to construct the item or assembly. In dentistry, fast prototyping is used to create actual-size, dimensionally accurate models of anatomical structures. These models are used to simulate procedures for a variety of complicated oral and maxillofacial conditions, including trauma, tumor removal, distraction osteogenesis, and—more frequently—dental implants. With these models, the practitioner can increase their confidence before the procedure and cut down on the amount of time needed for anesthesia and surgery.

Cone-beam Computed Tomography (CBCT) and stereophotography: [12]

Two of the most recent imaging modalities available for three-dimensional (3-D) viewing of craniofacial features are cone-beam computed tomography (CBCT) and stereophotography. For the diagnosis of dentofacial deformities, evaluation of the interaction of the hard tissue base with the soft tissue integument, monitoring and evaluation of changes over time, and planning orthognathic surgery, CBCT image scans can be fused with extraoral facial (photographic) or intraoral (impression) optical data.

CBCT and Artificial Intelligence: [13]

Deep learning (DL) techniques have been added to CBCT analysis to increase efficiency and accuracy in order to address these constraints. Dentists may have less work to do while viewing clinical radiological images as a result of substantial advancements made in the application of deep learning technology in CBCT exams. For tasks including automatic diagnosis, segmentation, categorization of teeth, inferior alveolar nerve, bone, airway, and preoperative planning, numerous DL models have been created. The workload of image reading can be significantly decreased by combining DL and CBCT.

Conclusion:

There is little doubt that the quick development and commercialization of CBCT technology specifically designed to image the craniofacial area will expand the number of 3D radiographic assessments available to dental practitioners in clinical dentistry practice.

With requirement of relatively low scanning times (10-70 seconds) and a reported radiation dose similar to that required for 4 to 15 panoramic radiographs, CBCT imaging offers doctors sub-millimeter spatial resolution images of good diagnostic quality thereby converting it from a desirable to an indispensable tool for dental practice.

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